Comparative Study of Holmium Laser Enucleation of the Prostate With MOSES Enabled Pulsed Laser Modulation

Tim Large, Charles Nottingham, Christa Stoughton, James Williams Jr., and Amy Krambeck

OBJECTIVE To compare outcomes for patients undergoing holmium laser enucleation of the prostate (HoLEP) for lower urinary tract symptoms secondary to benign prostate hyperplasia using 3 different laser fibers and 2 different laser energy modes.

MATERIALS AND METHODS This is a review of a clinic registry of men with lower urinary tract symptoms secondary to benign prostate hyperplasia who underwent HoLEP between August 2018 and January 2019. Patients were assigned to group 1 (50 patients), group 2 (50 patients), and group 3 (50 patients) based on the HoLEP being completed with either a Slimline 550μm, Slimline 1000μm, or MOSES 550 μm laser, respectively. The groups were compared using SSPS for ANOVA comparison of means and multivariate logistic regression.

RESULTS Ten patients who underwent concomitant stone surgery (2 PCNL, 8 ureteroscopy , 3 bilateral cases) and 11 patients had bladder stones removed; ancillary procedures did not significantly differ between groups(P = .2). Prostate enucleation times differed significantly (22.5 + 7.3, 16.4 + 6.9, 18.1 + 8.6 minutes $P \leq$.001) between groups. However, statistical significance was lost once enucleation time was indexed against enucleated tissue weight. Time to achieve hemostasis (minutes) was statistically different between groups (10.6 + 6.1, 7.7 + 5.2, 6.3 + 4.8 P <.001). This difference in hemostatic time was maintained on multilogistic regression demonstrating that MOSES laser enucleation was associated with a 3.9-minute decrease time to achieve hemostasis after enucleation compared to Slimline 550 HoLEP (P <.001).

CONCLUSION Our findings suggest that modulated pulsed laser energy can improve hemostasis during the enucleation phase of a HoLEP resulting in shorter Operating Room times. UROLOGY 136: 196−201, 2020. © 2020 Elsevier Inc.

Holmium laser enucleation of the prostate (HoLEP) is a versatile surgical option for the treatment of lower urinary tract symptoms due to benign prostate hyperplasia (LUTS/BPH).[1-3] Multiple randomized control trials comparing HoLEP to alternate BPH procedures have demonstrated short- and long-term safety, durability, and symptom relief after HoLEP.[4] Enucleation as a surgical technique for the treatment of BPH has been safely performed with a variety of energy sources including: bipolar electrocautery, GreenLight laser, Thulium, and Holmium laser energy.[5-7] Advancements in holmium laser technology have been limited and have mostly been centered around total power output by the laser units, however, modulated pulsed laser energy in high powered units has been introduced to optimize the efficacy of the laser. A specific example of this innovation has been developed and distributed by Lumenis as the MOSES laser platform. MOSES is a unique laser pulse pattern that displaces any fluid between the laser tip and target tissue allowing for more efficient energy delivery to the biologic target. A software and hardware upgrade to the Lumenis Pulse 120H system and single use MOSES laser fibers are required to perform a MOSES augmented HoLEP (m-HoLEP).

Despite HoLEP being heralded as the gold standard therapy for LUTS/BPH,[8] HoLEP only accounts for 5% of surgical interventions in the United States.[9] The most cited hurdle to a more universal adoption of the surgical technique is the learning curve associated with prostate enucleation.[10] Alternate surgical therapies include

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From the Department of Urology, Indiana University School of Medicine, Indianapolis, IN

Address correspondence to: Amy E. Krambeck, M.D., Department of Urology, Indiana University/IU Health Physicians, 1801 Senate Blvd Suite 220, Indianapolis, IN 46202. E-mail: akrambeck@iuhealth.org

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transurethral resection of the prostate, Rezume, Urolift, Aquablation, and robotic simple prostatectomy.[11] In the case of the surgical management of LUTS/BPH, HoLEP is capable of treating symptomatic BPH in conjunction with urolithiasis,[2] independent of gland size,[1] and in patients on antiplatelet or anticoagulation (AP and/or AT)[3] with robust long-term symptom relief.[12] The versatility and durability of Holmium technology makes it an optimal and cost-effective option for the surgical management BPH. Further improvements in laser efficacy seen with laser energy modulation offer the potential to improve short-term outcomes, reduce the learning without compromising long-term benefits of HoLEP.

Recent software engineering to modulate pulsed laser energy and novel laser fibers have been developed in an attempt to improve surgical performance of standard holmium-based procedures such as ureteroscopy and HoLEP. There is the hope that modulating laser energy might improve short-term outcomes and potentially ease the learning curve associated with surgery. After trialing the MOSES system for HoLEP, we observed favorable hemostatic properties during and after the enucleation process. Increased hemostasis affords the surgeon better vision during enucleation and morcellation and reduces the need for continuous bladder irrigation to avoid postoperative clot urinary retention. We sought to evaluation the efficiency and hemostatic properties of the MOSES laser technology (m-HoLEP), compared to standard laser technology (HoLEP) when utilized to perform a laser enucleation of the prostate.

METHODS

After IRB approval, a retrospective review of a prospectively maintained clinical registry of men undergoing HoLEP was performed. Between August 1, 2018 and Jan 31, 2019, 163 HoLEPs were performed at a single center by a single surgeon (AK). Because we are a tertiary referral center, 7 patients did not return for their postoperative evaluation and 6 patients had a corrupted laser log for peddle time and total laser energy used. Therefore 150 men were assigned to 3 groups based on whether their HoLEP was performed using a 550 μm (group 1), 1000 μm (group 2), or a 550 μm MOSES (group 3) fiber. The cases were accrued in a consecutive fashion with m-HoLEP being the preferred option as fibers were available. During the 6 months when a MOSES fiber was not available we would alternate cases with 550 and 1000 μm laser fibers. To keep cases consistent, all cases were completed using a Lumenis MOSES Pulse compatible120H dual peddle laser unit with maximal laser energy settings of 2 J and 40 Hz. Despite having 120 W, we did not exceed 80 W because of anecdotal evidence that the higher energy settings can result in increased dysuria during the postoperative recovery. Additionally, we learned that a narrow pulse width was beneficial for laser dissection during standard HoLEP enucleation and a widened laser pulse width with a lower energy setting of 1 J and 20 Hz was better for hemostasis during m-HoLEP and HoLEP. To minimize differences during the surgery, the same hemostatic settings were used in all cases—in the case of m-HoLEP, MOSES was disabled on the right (hemostatic) peddle. Therefore, the only difference between the groups was that MOSES was enabled when using the MOSES fiber during adenoma enucleation (left laser peddle), but disabled with the incompatible 550 and 1000 μm Slimeline SIS laser fibers.

By assigning the left foot peddle of the laser with cutting settings and the right peddle with hemostatic settings mentioned above, we could track the absolute time used to dissect the adenoma and to achieve hemostasis within the prostatic fossa. In all cases, HoLEP was completed in a standard 2 or 3 lobe, bottom-up, enucleation fashion with reduction in laser energy to 40 W (2 J and 20 Hz) during the apical turn near the sphincter complex, but otherwise maintained at 80 W (2 J and 40 Hz).[13] During prostate enucleation, bleeding vessels were cauterized using the right, hemostatic, peddle. Prior to prostate morcellation, the prostatic fossa was inspected and all bleeding vessels and surfaces were cauterized using the hemostatic peddle. This is our standard practice to optimize visualization during morcellation and help prevent bleeding related complications in the postoperative setting. Bladder stones too large to be evacuated through the 28-Fr resectoscope sheath were fractured with laser settings of 1 J and 30 Hz prior to prostate enucleation. Any other stone procedures were performed after the HoLEP was completed and data from this portion of the procedure was not included in the final laser analysis. At the conclusion of the case, the case registry log on the holmium laser unit was downloaded to a USB-drive. This data contained the absolute time of left and right peddle usage (minutes) and total used laser energy (kilojoules).

General demographics, patient symptom scores, retention status, perioperative outcomes, and 90-day complications were compared between the groups with a chi-squared analysis or an ANOVA comparison of means. Approximately 7 days after surgery our nursing staff contacted the patient to discuss pathology results and to assess for any concerning symptoms; specifically, the patients were questioned regarding persistent dysuria after surgery. AUA symptom scores and voiding metrics using a uroflow and bladder scanner were obtained at a 3-months post-HoLEP clinic appointment. Provided the patients had no clinical findings of a urinary tract infection or recent catheterization, a PSA blood test was obtained. Patients with incidental prostate cancer on their HoLEP specimen, a PSA greater than 1.5 ng/mL, persistent incontinence, or who requested, were provided a second follow-up appointment at 6 months. The remaining patients were released back to their referring providers. Patients who did not present to clinic were mailed a BPH packet that contained an International Prostate Symptom Score, Michigan Incontinence, and Sexual Health Inventory for Men scores. Complications up to 90 days postoperatively were evaluated by using the electronic medical record. The Clavien-Dindo classification system was used to categorize the complications.

Intraoperative evaluation of enucleation time (minutes) associated with specific fiber usage was controlled for with prostate gland size. To understand patient and intraoperative factors that influence time to achieve hemostasis, we performed a multiple linear regression model, adjusted for specimen size, patient age, and AT status, and type of fiber used to perform the procedure. Statistics were performed by a single statistician using JMP statistical software.

RESULTS

During the study period, 150 patients were included for analysis. Table 1 outlines the basic demographics between groups. There

Table 1. Preoperative characteristics

	Slimline 550	Slimline 1000	MOSES 550	*P*
	50	50	50	
Age	71 ± 8.2	70.3 ± 8.8	72 ± 9.0	.91
BMI	27.7 ± 5.3	27.9 ± 4.3	28 ± 5.9	.45
Prostate size	110.5 ± 85.5	118.3 ± 92.4	155.6 ± 50.3	.56
Pre-Op PSA	5.86 ± 4.8	8.59 ± 12.2	8.39 ± 5.9	.44
Pre-Op serum creatinine	1.34 + 1.1	1.34 + 1.7	1.16 + 0.4	.67
Urinary retention	22 (44%)	19 (38%)	16 (31%)	.47
Prior prostate biopsy	16 (32%)	16 (32%)	19 (36.5%)	.91
Hx of prostate cancer	1 (2%)	4 (8%)	4 (7.7%)	.63
Prior BPH surgery (Ave No.)	10 (1.2)	4 (1.3)	7 (1.4)	.11
Hx or urinary tract infections	5 (10%)	4 (8%)	4 (8%)	.91
Preoperative incontinence	10 (20%)	6 (12%)	6 (11%)	.89
Diabetes mellitus	7 (14%)	4 (8%)	9 (17%)	.41
Alpha-blocker	34 (68%)	40 (80%)	37 (71.2%)	.39
5-Alpha-Reductase Inhibitor	15 (30%)	8 (16%)	11 (21%)	.27
ASA score I	0	1 (2%)	0	
II	17 (34%)	8 (16%)	9 (17%)	
III	33 (66%)	39 (78%)	41 (79%)	
IV	0	2 (4%)	2 (4%)	.22
Antiplatelets/coagulants	15 (30%)	12 (24%)	15 (29%)	.83
Discontinue/bridged/continue	9/4/2	10/1/1	9/5/2	
Concomitant stone surgery	4 (8%)	5 (10%)	1 (1.9%)	.41
Concomitant cystolitholopaxy	5 (10%)	5 (10%)	1 (1.9%)	.23
Enucleation time (min)	47.1 ± 17.9	41.5 ± 14.6	40.9 ± 15.1	.01
Laser cutting time (min)	22.5 ± 7.3	16.4 ± 6.9	18.1 ± 8.6	<.001
Hemostasis time (min)	10.6 ± 6.1	7.7 ± 5.2	6.3 ± 4.8	<.001
Morcellation time (min)	11.6 ± 10.9	10.2 ± 13.5	10.3 ± 13.4	.68
Ave [range] Operating Room specimen Wt (g)	72.5[3-265]	65.9[4-315]	76.7[4-448]	.71
Change in Hgb (mg/dL)	1.5 + 1.2	1.5 +1.6	1.0 + 1.1	.02
Same day discharge	0	4	3	.02
Void and discharge within 24 hours	46 (92%)	41 (89%)	45 (92%)	.74

were no differences in age, comorbidities, American Society of Anesthesia physical status classification, BPH medication, or AP and/or AT status between the groups. There were 10 patients who underwent concomitant stone surgery (2 PCNL, 8 ureteroscopy , 3 bilateral cases) and 11 patients had bladder stones. Of note only 2 cases required lasering for the cystolithalopaxy (Table 1). Of the cohort, 57 men (38%) were in urinary retention and 42 (28%) were on AP and/or AT that required bridging in most cases (Table 1).

Intraoperative enucleation times (P = .01) and cutting peddle utilization times were significantly less (P <.001) between the groups. However, statistical significance was lost once these times were indexed against enucleated tissue weight. The volume of prostate adenoma enucleated ranged from 8 to 488 g with no statistical difference between the mean grams enucleated in each group (72.5 ± 49.6, 65.9 ± 63.6, 76.7 ± 77.1, for groups 1, 2, and 3, respectively; P = .7). Time to achieve hemostasis (minutes) (ie, use of the right peddle) was statistically different between the different groups (10.6 ± 6.1, 7.7 ± 5.2, 6.3 ± 4.8 P <.001).

Averaging the postoperative changes in hemoglobin compared to the baseline hemoglobin showed statistical difference between the MOSES group and the other 2 groups (Group 1 was 1.5 ± 1.2, Group 2 was 1.5 ± 1.6, Group 3 was 1.0 ± 1.1 △mg/dL; $P \leq .02$); however, the clinical relevance of the observed difference is somewhat limited. There were 145 patients admitted as an outpatient in a bed with 91% discharging home in less than 24 hours without a catheter. There were 7 patients (4.6%) who required a single in-and-out catheterization and then voided spontaneously and 4 (2.6%) required a catheter at discharge with 100% removal within 72 hours. Two patients had a prolonged hospital stay, the first of which had a myocardial infarction prior to HoLEP requiring AP and/or AT causing clot urinary retention that was remedied with a bed side irrigation (Clavien IIIa-group 2). The second patient had a prolonged presurgical hospitalization and was originally admitted with urinary retention, bacteriuria, and bacteremia prior to HoLEP. The patient required a 48-hour post m-HoLEP stay because of deconditioning. Nine (5.9%) patients experienced a complication within 90 days of surgery (Table 2). In addition to the abovementioned patient who required a bed side clot evacuation (IIIa), there was a single patient in group 1 who restarted his third generation AT 2 days after discharge went into clot urinary retention requiring an anesthetic and clot evacuation (IIIb). Four other patients presented to the emergency room with hematuria requiring reassurance (2 patients—Clavien I) and a urinary tract infection requiring antibiotics (Clavien II). There were no transfusions, no intensive care admission, and no deaths in this study.

The average follow-up for the group was 13.7 + 1.6 weeks with 78% of patients presenting to their 3-month postoperative clinic appointment. All patients who do not present for follow-up were mailed a questionnaire packet with the same metrics they completed preoperatively. Postoperatively, there were no differences in rates of dysuria beyond 2 weeks, voiding function or urinary quality of life scores between the groups (Table 2). Average reduction in AUA symptom scores ranged from 12.5 to 13.5 ± 3.3 with the group 3 patients having the most pronounced improvement of 5.5 ± 4.6 (P = .01). Incontinence rates were measured with the Michigan Incontinence Symptom Index and were equivalent

Table 2. Postoperative outcomes

	Slimline 550	Slimline 1000	MOSES 550	*P*
Average f/u [wk]/No. of patients	14.8 + 6.1 [38]	14.7 + 5.1 [42]	14.4 + 5.2 [39]	.8
Pre-Op AUAss (Mean/Median)	21/20	20/21	19/18	.2
Post-Op AUAss (Mean/Median)	7.5/6.5	6.5/6.5	5.5/2.5	.01
Post-Op MISI Score (Mean/Median)	7.5 + 7.8	10.5 +7.2	8.9 + 6.9	.1
Post-Op MISI Bother (Mean/Median)	0.65 + 1.4	1.02 + 1.2	0.73 + 1.1	.5
Post-Op Quality of life	1.2 + 1.2	1.1 +1.6	1.9 + 1.1	.4
Post-Op max flow rate	21.7 + 5.5	20.5 + 9.6	22.1 + 10.8	.2
Post-Op average flow rate	15.8 + 9.4	14.7 + 5.5	19.1 + 7.1	.2
Post-Op post void residual	95.4 + 101.3	59.8 + 42.8	62 + 59.9	.4
Post-Op PSA	1.5 + 1.4	0.7 + 0.5	0.8 + 0.8	.4
Did not void and discharge <24 h				.8
Voiding issues	4 (8%)	4 (8%)	3 (5.7%)	
Prolonged Length of stay	0	1 (2% - Clavien IIIa)	1 (1.9%)	
Incontinence at 3 mo	1 (2%)	1 (2%)	2 (1.3%)	.6
Dysuria beyond 2 weeks post-op	0	3 (6%)	1 (1.9%)	.2
Emergency room visit	2 (4%)	1 (2%)	1 (1.9%)	.5
Clavien-Dindo classification I	1 (2%)	1 (2%)	0	
II	1 (2%)	2 (4%)	2 (3.8%)	
III	1 (2%)	1 (2%)	0	
90-day complications	3 (6%)	4(8%)	2 (1.3%)	.4

MISI, Michigan Incontinence Symptom Index.

between all 3 groups (Table 2). There were 5 patients with new persistent incontinence based on Michigan Incontinence Symptom Index (Table 2) of which, 4 followed up at 6 months after further pelvic floor and additional anticholinergic therapy with resolution of their incontinence.

To better understand the relationship between specific fiber usage and the time required to achieve hemostasis, we performed a multilogistic regression. This was of particular interest given the same laser energy settings of 1 J and 20 Hz with a wide pulse width was assigned to the right peddle in all 3 groups. The 550 μm laser fiber was established as the standard case to evaluate the effects of patient age, preoperative presence of a urinary catheter, AP and/or AT status, and use of the SIS 1000 or MOSES 550 fiber on the time required to achieve hemostasis. Based on the logistic regression, fiber type independently affected time to achieve hemostasis with MOSES having the greatest affect (3.9-minute decrease hemostatic peddle time) compared to the Slimline 550 HoLEP (*P* <.001—Table 2). This suggests that during enucleation m-HoLEP is more hemostatic and requires less time to achieve hemostasis after enucleation. This was more evident as prostate volume, shown to increase time to achieve hemostaisis (Table 3), had less affect when using MOSES technology (Fig. 1).

DISCUSSION

This is the first comparative study, to our knowledge, of a modified pulsed holmium laser system used to enhance HoLEP. Intraoperatively, we noted a significant decrease in enucleation time and hemostasis time with the MOSES system, with persistent decrease in hemostasis time after multivariate analysis (Table 3). This multivariate analysis suggests that for every 10-g increase in prostate gland size, there is approximately a 40% increase in time to achieve hemostasis with a standard 550 micron fiber; this is reduced 3.9-fold when using pulse modulated laser technology and a MOSES 550-fiber. These benefits are modest but with further improvements in the energy modulation, along with further development in laser fiber technology, a more clinically significant impact is likely to occur. Demonstrating improved hemostasis can be challenging. With m-HoLEP we noted a significantly smaller decrease in hemoglobin from preoperative levels, and while this has a limited clinical impact, it does help support the added hemostatic potential of a modified pulsed laser energy. Furthermore, standard outcomes such as change

Table 3. Multilogistic regression for variables that affect time to achieve hemostasis

	Coefficient	95% CI (min)	*P* Value
Fiber type			
550 laser	–	–	–
1000 laser	−2.09	−3.48 to −0.71	.003
MOSES laser	−3.89	−5.26 to −2.53	<.001
Anticoagulation	0.82	−0.55 to 2.19	.238
Age	0.04	−0.03 to 0.11	.290
Indwelling catheter	0.77	−0.43 to 1.12	.222
Specimen weight, in 10 g increments	0.61	0.52-0.70	<.001

This table represents the multilogistic regression for variables that affect time to achieve hemostasis. The control was a 550 μm laser fiber with time affects (minutes) to achieve hemostasis expressed via 95% confidence interval (CI). Only fiber type and gland size exclude the null value.

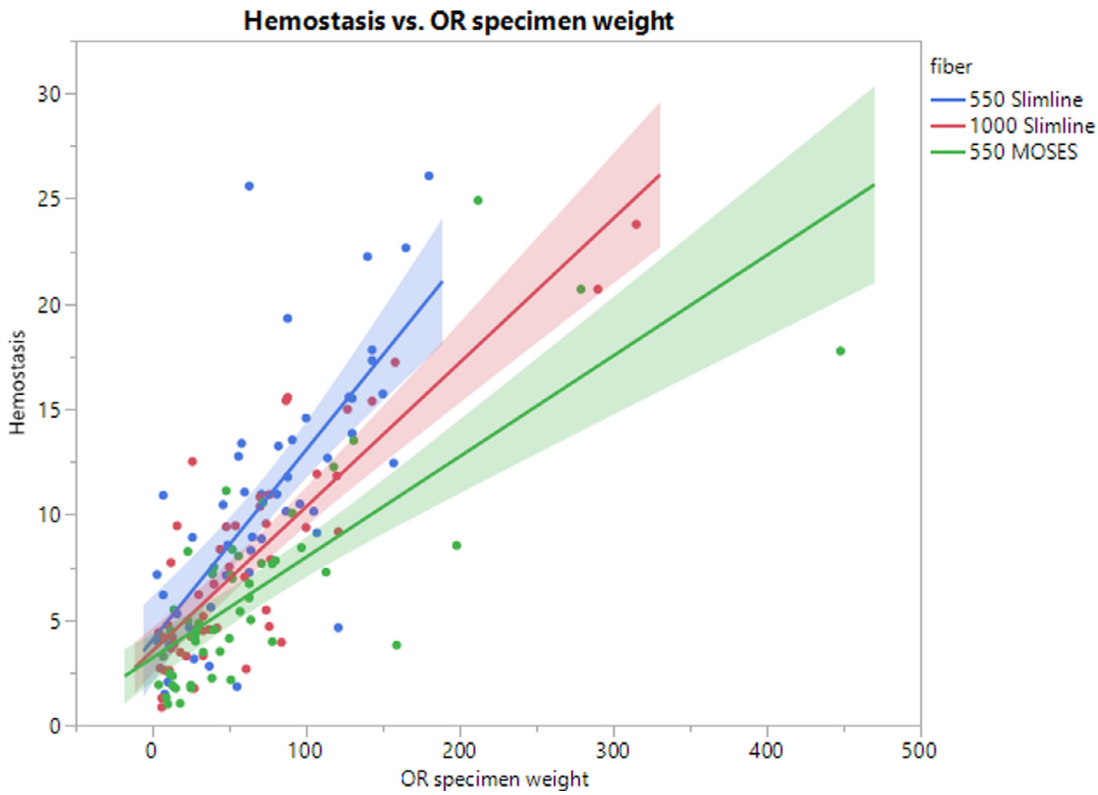

Figure 1. This is a graph demonstrating the inverse relationship of gland size (g) to time to achieve hemostasis (minutes) stratified by laser fiber. The green line represents 550 MOSES fiber enucleation. The slope of the line is a surrogate for hemostatic efficiency. The flatter the line the more hemostatic the enucleation process. (Color version available online.)

in symptom scores, flow rates, incontinence, and dysuria were no different among groups.

The MOSES effect was first described in 1986 but was not optimized for clinical use in urology until 2017 with the release of the MOSES technology by Lumenis. The specific wavelength (~2.1 μm) of holmium laser energy is highly absorbent and dissipates easily within water. The MOSES laser system modulates the pulsed laser energy to create an initial vapor bubble, which displaces any fluid between the target and laser tip. At the same time a vapor tunnel is created, through which, subsequent laser energy can pass with low attenuation delivering the maximal energy to the target.[14] The first application of MOSES technology was for the treatment of nephrolithiasis.[15,16] Given the overlap in patients, providers and technologies for surgical stone and BPH treatment, the use of MOSES technology for HoLEP was a natural progression. In our experience, while we endorse that there are modest clinical differences between m-HoLEP and standard HoLEP, we do feel that MOSES technology can be safely implemented into a HoLEP practice and potentially improve the surgical experience.

m-HOLEP builds on a robust surgical technique with exceptional short- and long-term outcomes to further optimize on specific goals of BPH surgery; namely hemostasis.[17] The interaction between the laser fiber and prostate tissue is critical for efficiency and completeness of the enucleation. The objective of HoLEP is to quickly identify the surgical capsule, stay within the surgical plane, and maintain hemostasis throughout the case.[18] Obscured planes from tissue charring[19] or a heavy reliance on mechanical enucleation with the cystoscope can prolong surgery, increase hematuria and murky vision, and can result in postoperative bleeding complications. We observed a favorable when performing m-HoLEP. Group 3 had 15% faster enucleation, 40% faster hemostatic times, and was less affected by increases in prostate gland size (Fig. 1). This is the first application of a modified pulsed holmium laser energy applied to prostate enucleation, and even though the results are modest, we do feel there is value in using m-HoLEP for surgical BPH therapy. The improvements in hemostasis could potentially help the novice surgeon overcome the learning curve by improving vision clarity.

A major concern with the adoption of procedures requiring new technology is the cost associated with equipment upgrades. In a cost savings approach many urologists are utilizing a lower powered holmium laser, typically used for stones, to perform HoLEP for LUTS/BPH.[20] Even though low power enucleation of the prostate is feasible, there are many benefits, outlined in this paper, to using a high-powered laser system. One of the largest impacts on overall cost of care is reducing the need for a hospital stay after surgery. In one study, day-case HoLEP was successful in 83.4% of same day HoLEPs with all failed cases stemmed from urinary bleeding.[21] Utilizing a laser that is associated with improved hemostasis can improve the chances of a successful outpatient BPH practice. In this study we demonstrated that increasing prostate size, which increases bleeding (Table 3) and delays time to achieve hemostasis is reduced when performing m-HoLEP (slope of green line—Fig. 1). These findings could help the advanced surgeon transition to a consistent outpatient HoLEP practice.

This publication is not without limitations. It is a retrospective review of a single center, single surgeon experience and may not be applicable to all hospital systems. Patients were not prospectively randomized, but rather were enrolled in a contiguous fashion. With this study model, there may be concerns that the surgeon improved, or the surgical technique evolved during the study, which resulted in the better hemostasis. However, the study represents a 6-month period in a 10-year history of performing HoLEP by a single surgeon. There are resident and fellow involvement in the enucleation portion of the procedure, however, the task of achieving hemostasis after enucleation is complete is performed exclusively by the staff surgeon. This supports the improved hemostatic properties of the modulated pulsed laser energy. Therefore, we feel that it is a reasonable conclusion that the evolution in laser technology is positively affecting the procedure. Additional work is needed to better characterize the extent to which this technology is responsible for achieving hemostasis and what further advances in this field may yield for the procedure. There were 10 patients who had concomitant stone surgery, but this did not affect the analysis as division of the case was achieved by selecting only times the 550-micron laser fiber was in use. Long-term data regarding the effects of MOSES laser technology is limited; however, given the favorable 3 months data and identical surgical technique we expect similar outcomes such as s-HoLEP after 10 years.[12] Despite these limitations, this study is the first to demonstrate improved efficiency and hemostasis of HoLEP performed with a pulse modulating holmium system and optimized laser fiber technology.

CONCLUSION

Using modulated pulsed holmium laser energy to enhance prostate enucleate is safe and effective. This study used the MOSES platform by Lumenis to generate a modified pulsed laser energy, however, there are other platforms emerging with pulsed-modulated laser technology. m-HoLEP was increased Operating Room efficiency and hemostasis regardless of prostate size compared to s-HoLEP.

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